

Title: Searching for Dark Photon and Dark Higgs Particles with the SeaQuest Spectrometer at Fermi laboratory

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Lead Experimenters: Ming Liu (PI), Kun Liu (co-PI), Hubert van Hecke, Pat McGaughey, Sho Uemura, Sanghoon Lim, Xuan Li, Alexander Wickes

The SeaQuest/E906 experiment at Fermi laboratory is primarily designed to study the quark and anti-quark structure of the nucleon and its modification inside nucleus by measuring high-mass Drell-Yan production in $p+p$ and $p+A$ collisions with various nucleus targets. The experiment uses a 120 GeV/c proton beam from the Fermi lab main injector. Figure 1 shows the SeaQuest/E906 spectrometer consisting of two dipole magnets and four tracking stations. The target is about 6% of nuclear interaction length, so most of protons interact with the beam dump which provide a large number of $p+Fe$ collisions. This condition is suitable for a parasitic run to explore the dark sector in high-energy $p+A$ collisions with 1.44×10^{18} POT (considering the upcoming E1039 experiment).

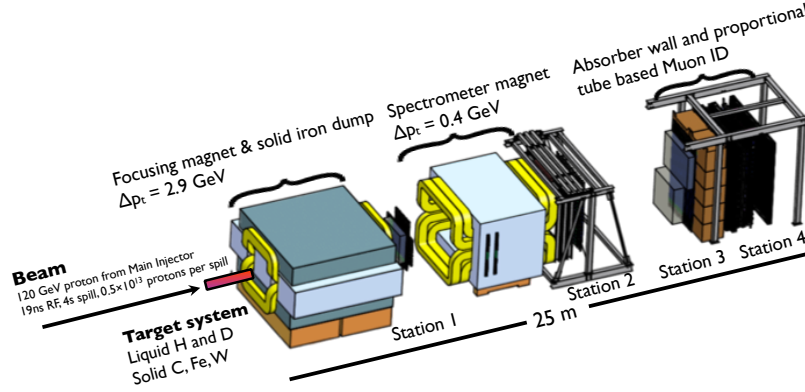


Figure 1: The SeaQuest/E906 spectrometer.

One of channel to access the dark sector is so called dark photon (A') which is expected to interact feebly with the normal matter by kinematic mixing with the regular photons as shown in the left Feynman diagram of Fig. 2. According to the dark matter phenomenology models, the mass of dark photon is likely to be in between $1 \text{ MeV}/c^2$ and $10 \text{ GeV}/c^2$, and the current E906 spectrometer has an excellent capability to measure dimuons in this mass range. Another channel is dark Higgs (ϕ) which can be obtained from the electroweak symmetry breaking of the standard model Higgs boson as shown in the right Feynman diagram of Fig. 2. These dark photon and Higgs are feebly interaction with the normal matter, the decay vertex will be largely displaced from the production vertex. Due to the 5 m length of solid iron beam dump/magnet, most of particles other than neutrinos and muons are stopped before penetrating 1/3 of the beam dump.

Therefore, the displaced decay vertex can help us to distinguish between SM particles and dark photons (Higgs).

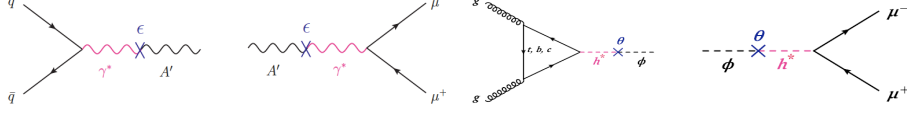


Figure 2: Feynman diagrams for production of dark photon (left) and dark Higgs (right) and their decay into muon pairs.

In order to reconstruct the displaced decay vertex and reject background events, a moderate upgrade of trigger system has been proposed. From the initial studies, a scintillating-strip tracking detector located in between the tracking station 1 and 2 could satisfy the requirements. Two types of detectors are illustrated in Fig. 3. The left frame, consisting of 80 scintillator bars ($1 \times 1 \times 80$ cm³), is for upstream, and the right frame of 50 scintillator bars ($1.5 \times 1.8 \times 100$ cm³) is for downstream. In each scintillator bar, two wave-length shifting fibers are inserted to collect light, and the polished end of these fibers are in contact to a SiPM and preamp card. From the test with a prototype, the efficiency is higher than 96%. There is also an calibration system with pulser board of red LEDs to check whether each channel is working. An signal input fiber connects to the coupler (green and red boxes in Fig. 3) and distribute light to 19 clear fibers, and each clear fibers is inserted into each scintillator bar. Each trigger station is composed of 4 boxes of 50 or 80 bars. By incorporating with the existing tracking station 4, ~ 30 cm of z -vertex resolution for dimuons of $0.2 < M < 2$ GeV/ c^2 can be achieved based on simulation study. These detectors have been built during the last few months in LANL, and they are now under commissioning in Fermi lab.

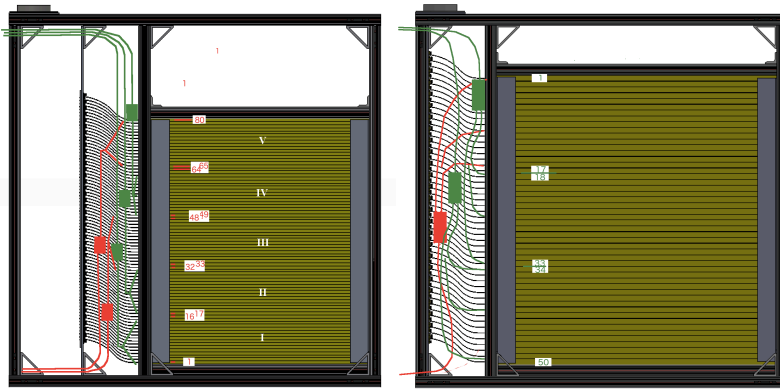


Figure 3: Schematic view of trigger detectors of 80 scintillator bars for station 1 (left) and 50 scintillator bars for station 2 (right).

